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(54) **BIASING A PHASE CHANGE MEMORY DEVICE**

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G11C 11/00 (2006.01)

(57) **ABSTRACT**

(52) **U.S. Cl.** **365/163**; 365/148; 365/158;
257/2; 257/5; 257/52

A phase change memory device includes a plurality of cells connected to bitlines and including respective phase change memory elements and cell select devices and an addressing circuit for selectively addressing at least one bitline and one cell connected thereto. A reading column bias circuit supplies a bitline voltage to the addressed bitline and cell. The bitline voltage includes the sum of a safe voltage and a reference select device voltage, wherein the reference voltage is equal to a select device voltage on the select device when a cell current flowing through the phase change memory element and the cell select device is equal to a safe current. The safe voltage and the safe current are such that phase transition of the phase change memory element is prevented in any bias condition including a cell voltage lower than the safe voltage and in any bias condition including the cell current lower than the safe current.

(58) **Field of Classification Search** 365/163,
365/148, 158; 257/2, 5, 52

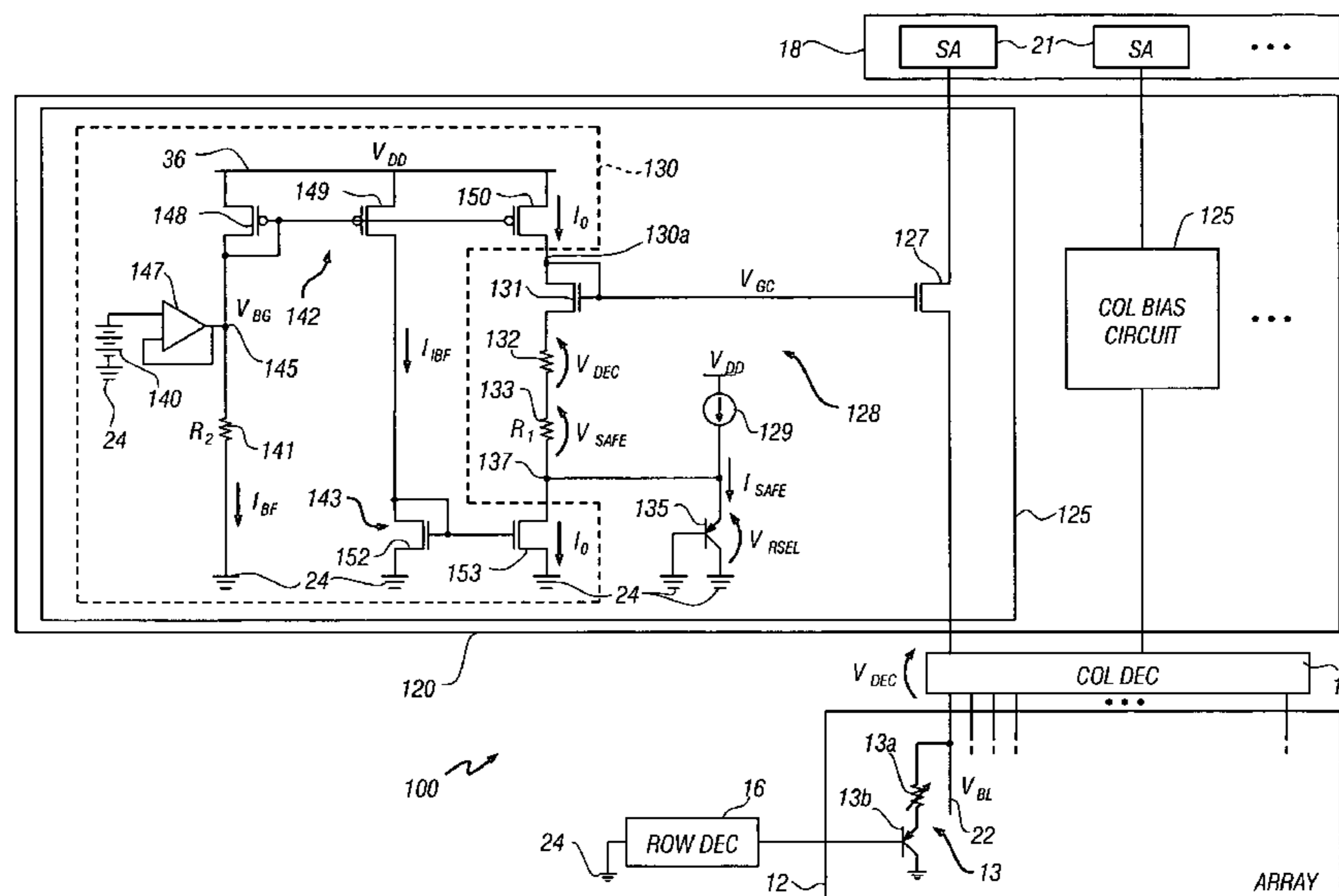
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19 Claims, 4 Drawing Sheets



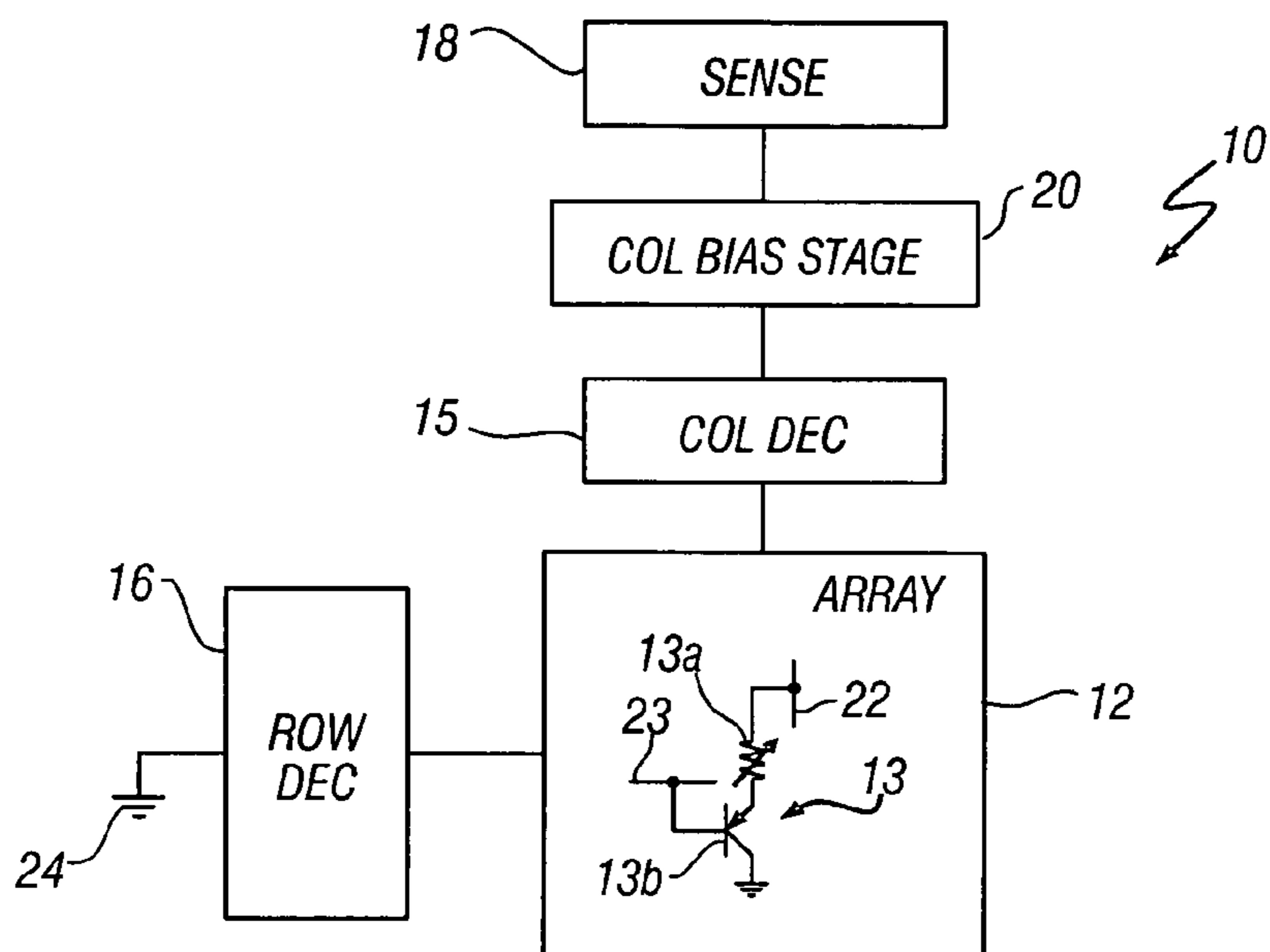


FIG. 1

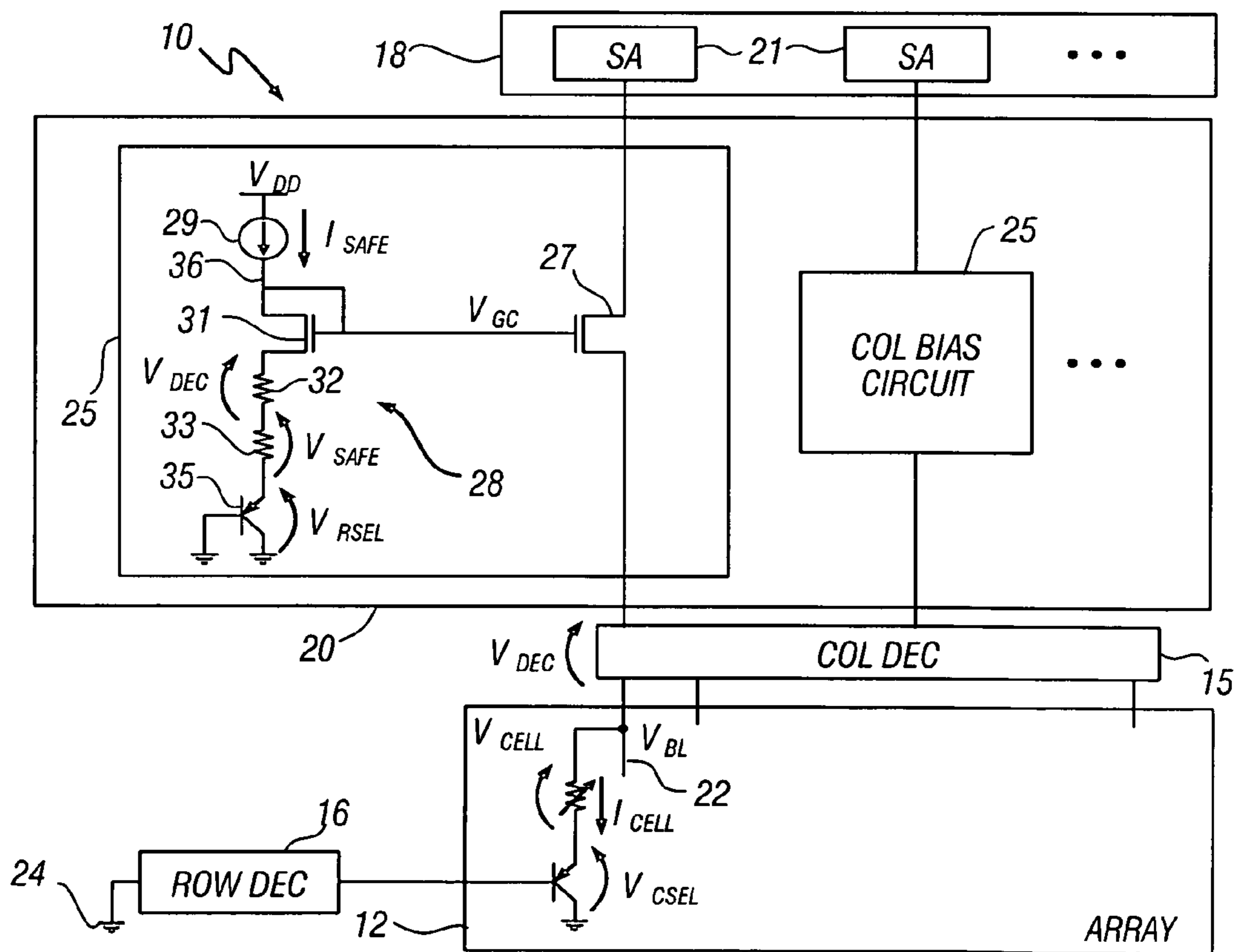


FIG. 2

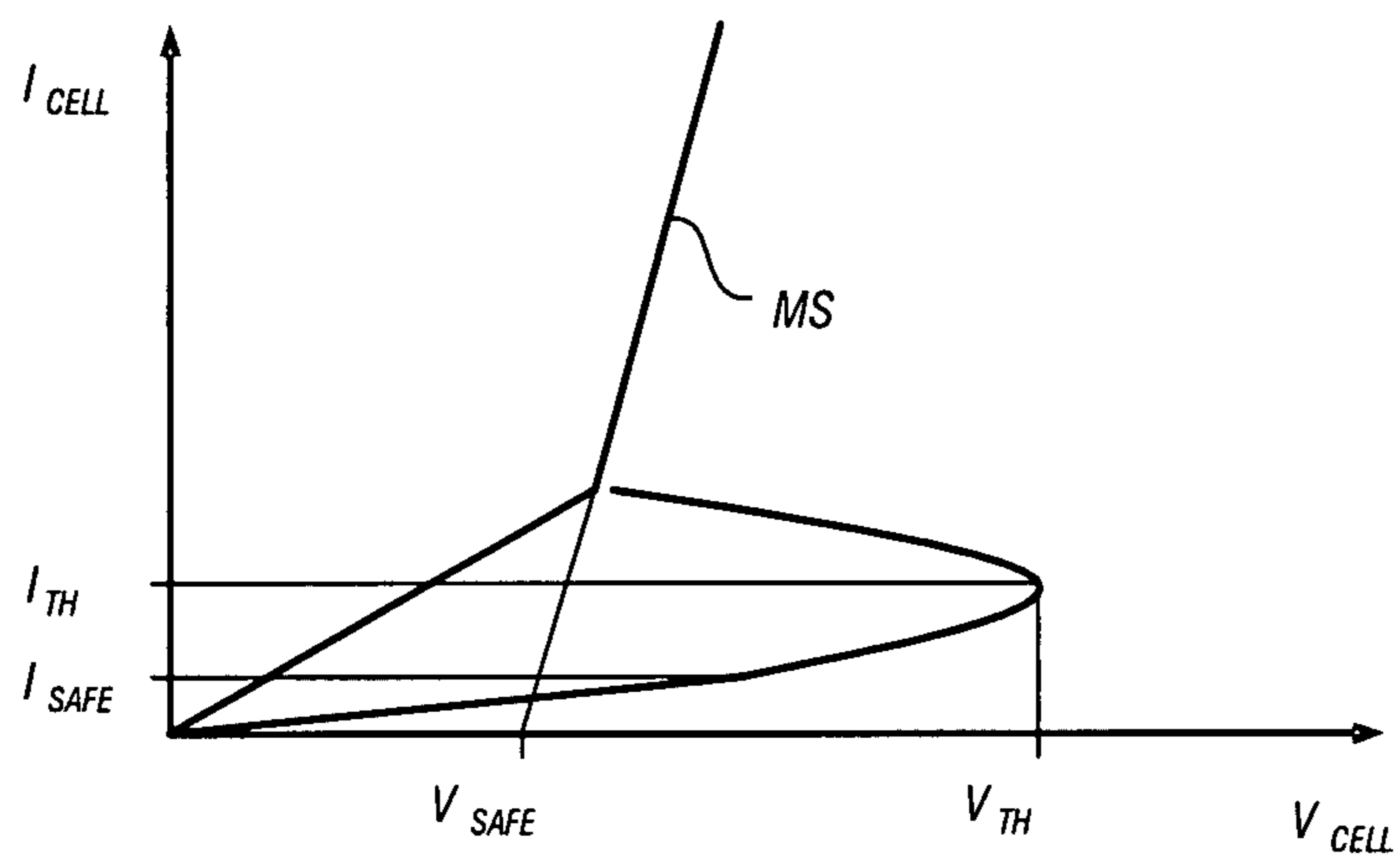


FIG. 3

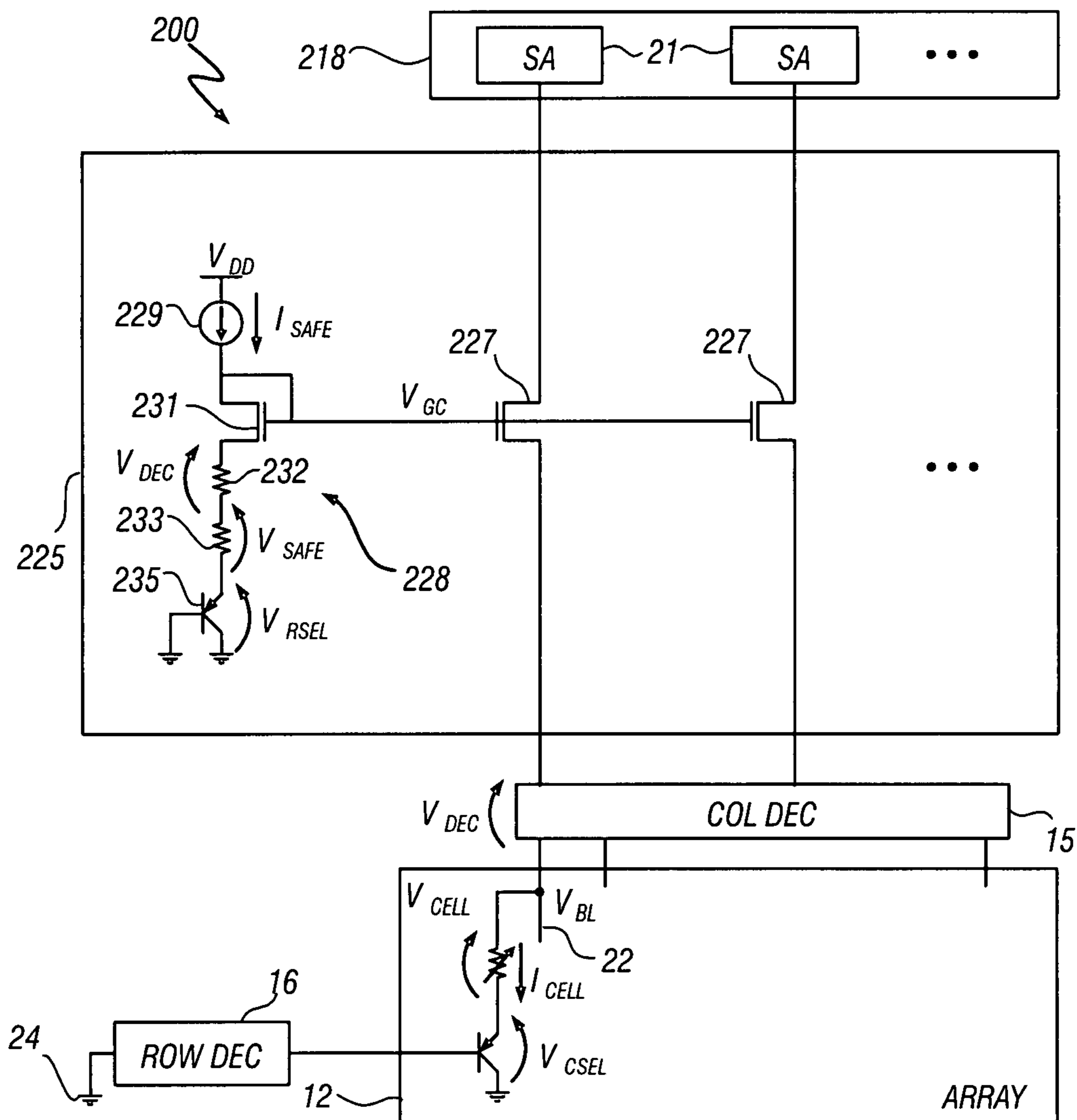


FIG. 5

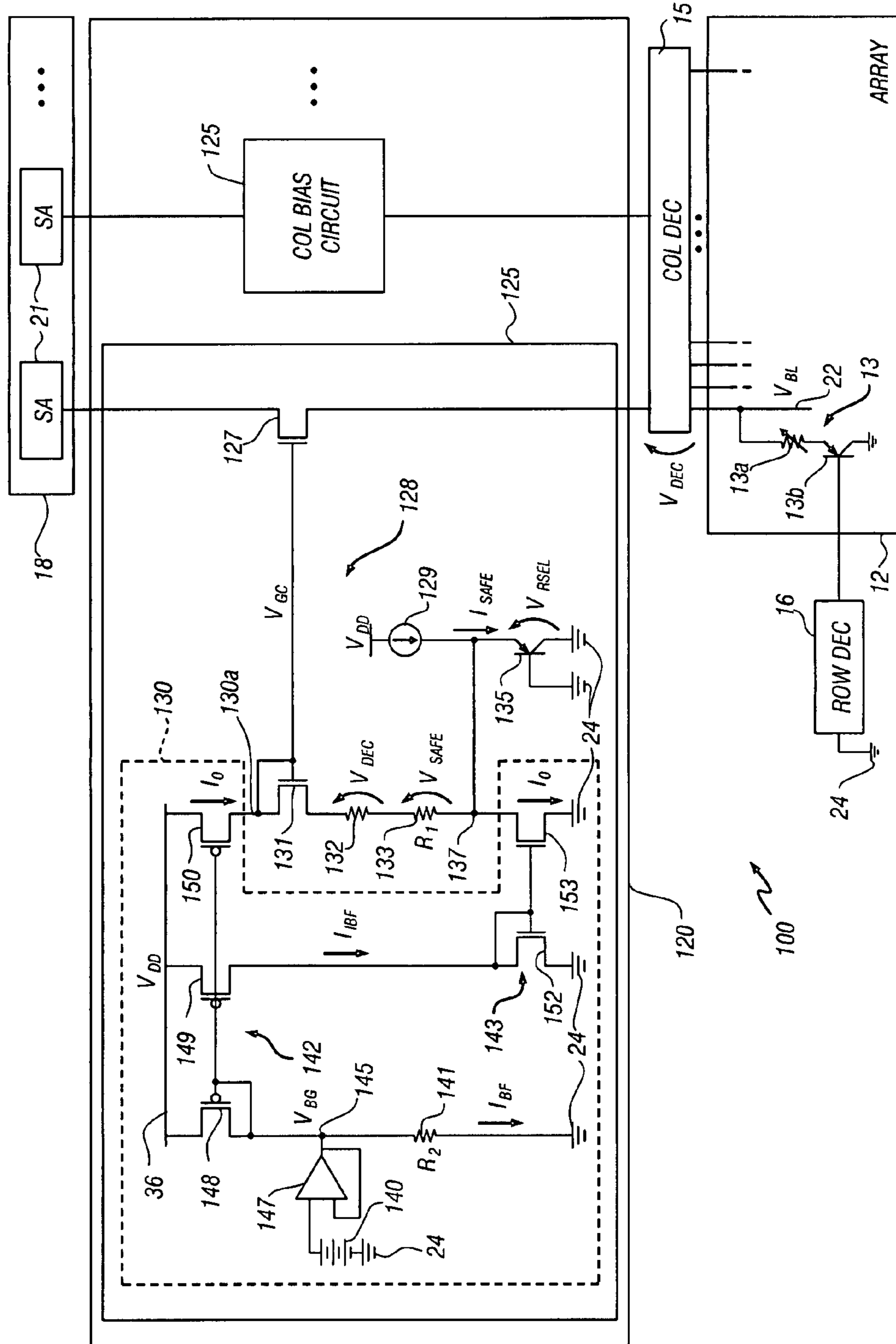


FIG. 4

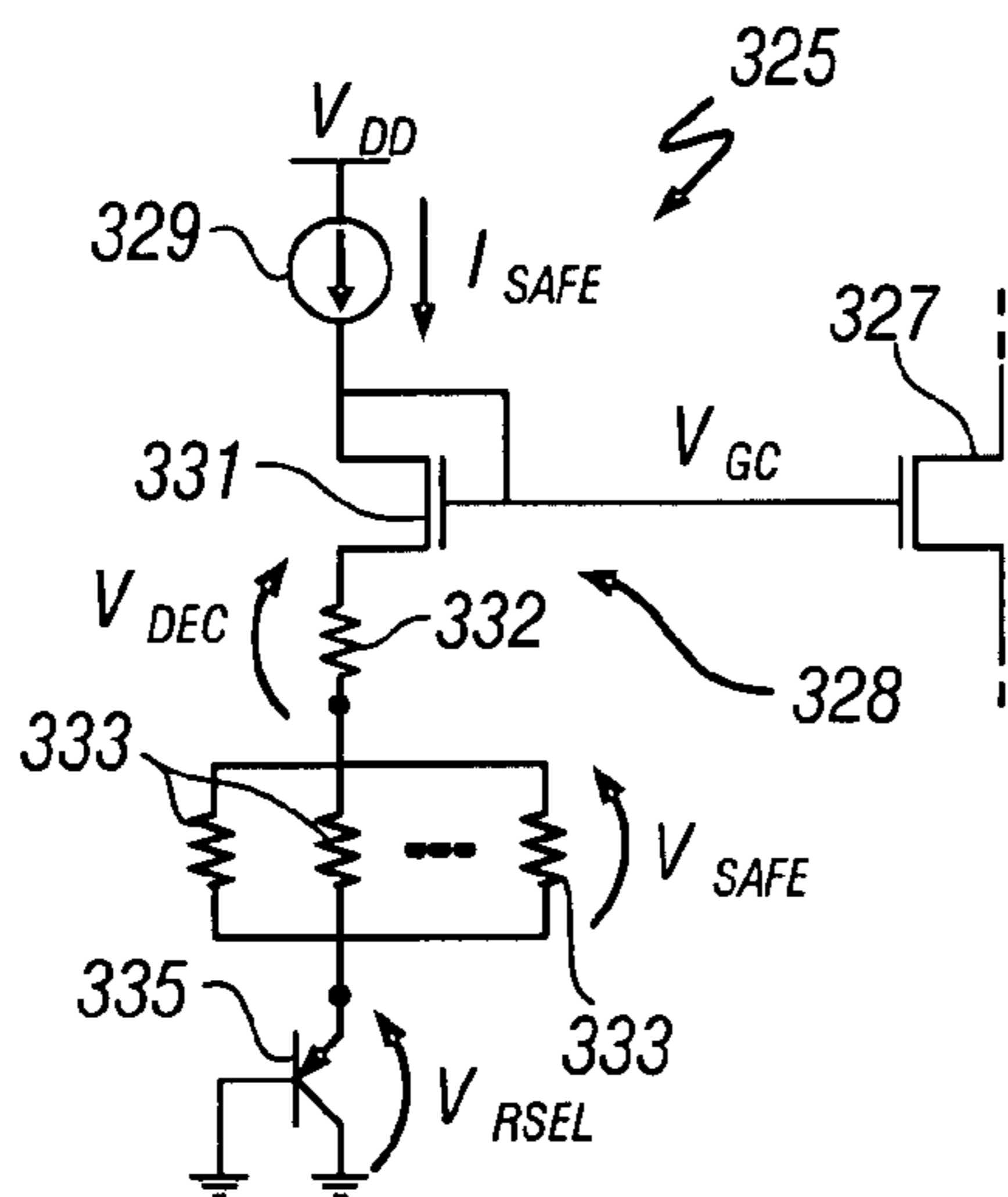


FIG. 6

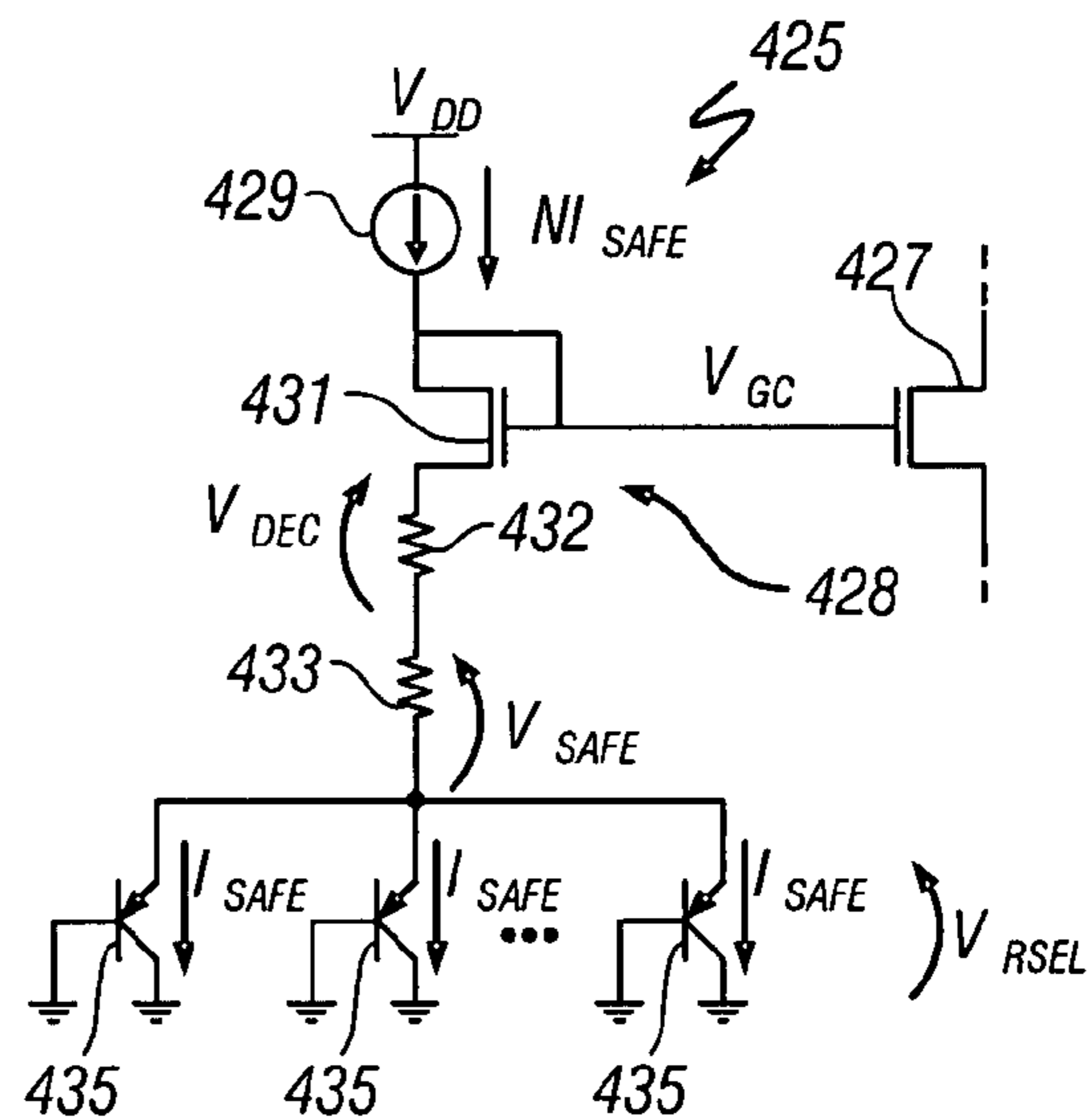


FIG. 7

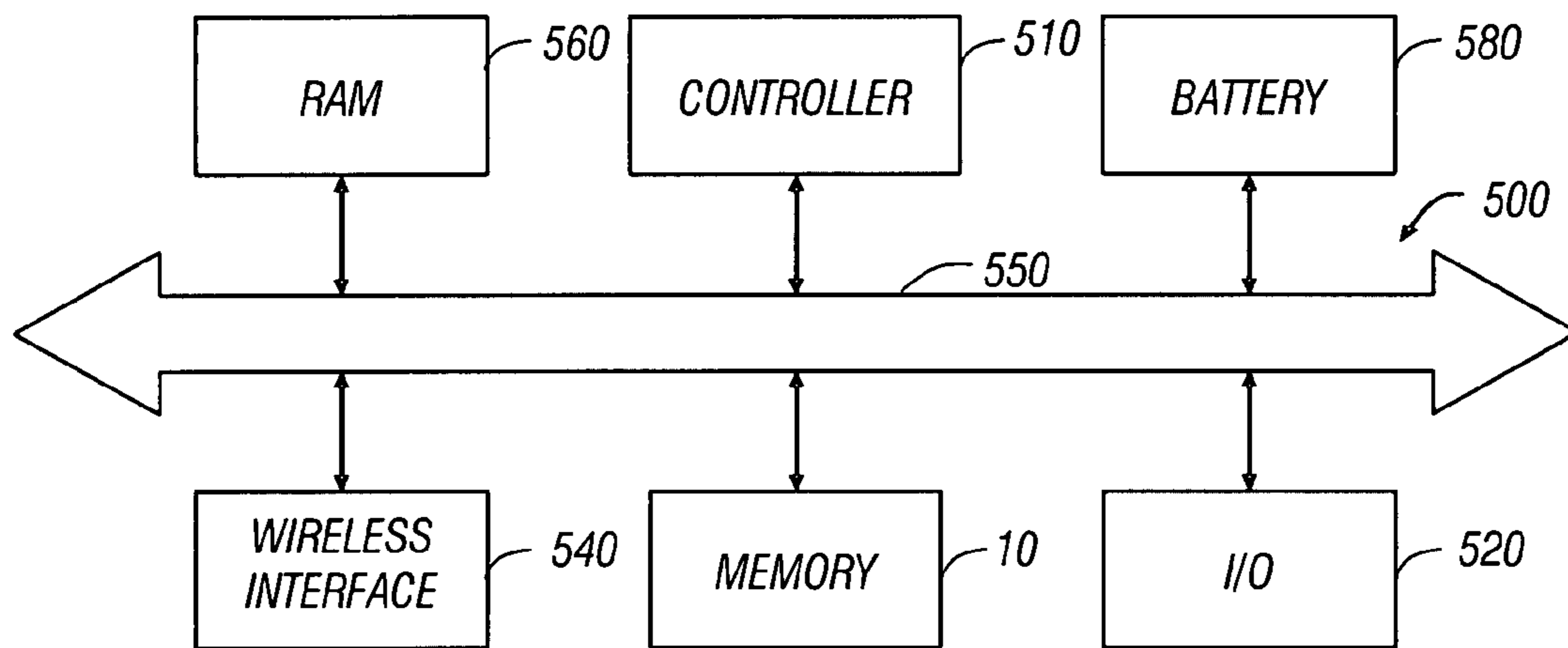


FIG. 8

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BIASING A PHASE CHANGE MEMORY
DEVICE

BACKGROUND

This relates generally to a phase change memory device.

Phase change memory arrays use a class of materials which have the property of changing between two phases having distinct electrical characteristics. For example, these materials may change from an amorphous phase, which is disorderly, to a crystalline or polycrystalline phase, which is orderly, and the two phases are associated with considerably different values of resistivity.

At present, alloys of elements of group VI of the periodic table, such as Te or Se, referred to as chalcogenides or chalcogenic materials, can advantageously be used in phase change cells. The chalcogenide that currently offers the most promise is formed by a Ge, Sb and Te alloy (Ge₂Sb₂Te₅), referred to as GST.

In chalcogenides, the resistivity varies by two or more orders of magnitude when the material passes from the amorphous phase (more resistive) to the crystalline phase (more conductive) and vice versa.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a simplified block diagram of a phase change memory device according to a first embodiment of the present invention;

FIG. 2 is a hybrid circuit and block diagram of the phase change memory device of FIG. 1;

FIG. 3 is a plot of a I-V characteristic of a PCM cell of the phase change memory device of FIG. 1;

FIG. 4 is a hybrid circuit and block diagram of a phase change memory device according to a second embodiment of the present invention;

FIG. 5 is a hybrid circuit and block diagram of a phase change memory device according to a third embodiment of the present invention;

FIG. 6 is a circuit diagram of a portion of a phase change memory device according to a fourth embodiment of the present invention;

FIG. 7 is a circuit diagram of a portion of a phase change memory device according to a fifth embodiment of the present invention; and

FIG. 8 is a system depiction of one embodiment of the present invention.

DETAILED DESCRIPTION

With reference to FIG. 1, a phase change memory device 10 comprises an array 12 of cells 13, that are arranged in rows and columns, a column decoder 15, a row decoder 16, a sense stage 18 and a reading column bias stage 20.

FIG. 1 illustrates a typical cell 13 of the array 12. A cell 13 includes a phase change memory element 13a and a select device 13b coupled in series. The phase change memory element 13a includes a portion of a phase change material and is therefore suitable for storing data in form of respective resistance levels associated to different phases of the phase change material, as above explained. In FIG. 1, the phase change memory element 13a is illustrated as a resistor having variable resistance level.

In one embodiment, the select device 13b are PNP bipolar transistors controlled to allow currents flow through selected memory elements 13a during read and program/verify operations. The cells 13 are further connected to respective bitlines

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22 (directly) and word lines 23 (through the select device 13b). For the sake of simplicity, moreover, in the embodiment described, the cells 13 allow two different programmable resistance levels, to store one bit each. However, in other embodiments, multilevel cells, capable of storing more than one bit each, may be used.

Groups of cells 13 are selectively addressable by the column decoder 15 and the row decoder 16, which connect selected bitlines 22 to the reading column bias stage 20 and selected word lines 23 to a ground line 24, respectively. In the embodiment described, the ground line 24 is used as a read voltage supply line for the selected word lines 23.

The addressed cells 13 are read by the sense stage 18. As illustrated in FIG. 2, the sense stage 18 comprises a plurality of sense amplifiers 21, connectable to respective addressed bitlines 22 via the column decoder 15.

The reading column bias stage 20 comprises a plurality of reading column bias circuits 25, each coupled to a respective sense amplifier 21 for biasing bitlines 22 selected for reading. FIG. 2 shows a simplified circuit diagram of one of the reading column bias circuits 25.

Each reading column bias circuit 25 comprises a cascode transistor 27 and a voltage control circuit 28, for providing a controlled bias voltage V_{GC} on a gate terminal of the cascode transistor 27. In one embodiment, the cascode transistor 27 is a NMOS transistor and has its drain terminal connected to a respective sense amplifier 21 and source terminal connected to the column decoder 15 for coupling with an addressed bitline 22.

The voltage control circuit 28 comprises a current source 29, a diode-connected bias transistor 31, a dummy resistor 32, a reference resistor 33 and a reference selector 35, all of which are series-connected.

The current source 29 is connected to a voltage supply line 36 and is configured to supply the bias transistor 31, the dummy resistor 32, the reference resistor 33 and the reference selector 35 with a controlled safe current I_{SAFE} . The safe current I_{SAFE} is selected so that if a read cell current I_{CELL} , that flows through an addressed cell 13 during reading operation, is lower than the safe current I_{SAFE} , a read disturb is avoided, whatever read cell voltage V_{CELL} is dropped by the phase change memory element 13a of the addressed cells 13. As illustrated in FIG. 3, the current values above the safe current I_{SAFE} in the I-V characteristic of a cell 13 in the amorphous state shows non-linearity. In particular, phase transition of the phase change memory element 13a is prevented in any bias condition such that the read cell current I_{CELL} is lower than the safe current I_{SAFE} , irrespective of the resistance level of the addressed cells 13.

The bias transistor 31 may be an NMOS transistor designed to match the cascode transistor 27. The gate terminal of the bias transistor 31 may provide the bias voltage V_{GC} and is directly connected to the gate terminal of the cascode transistor 27.

The resistor 33 may conveniently be made of the same phase change material as the phase change memory elements 13a of the cells 13 (e.g. GST). In one embodiment, the phase change material forming the resistor 33 is in its crystalline state. A resistance value of the reference resistor 33 is such that a predetermined safe voltage V_{SAFE} is dropped across the resistor 33 when the current source 29 supplies the safe current I_{SAFE} . The safe voltage V_{SAFE} is in turn selected so that if the read cell voltage V_{CELL} that is dropped across the phase change memory element 13a of addressed cells 13 during reading operation, is lower than the safe voltage V_{SAFE} , reading is not affected by disturbs, whatever the read cell current I_{CELL} flowing through the addressed cells 13.

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With reference again to FIG. 3, the safe voltage V_{SAFE} is the voltage value at which the voltage axis is intercepted by virtually extending a melt-state section MS of the I-V characteristic of a cell **13**. In particular, phase transition of the phase change memory element **13a** is prevented in any bias condition such that the read cell voltage V_{CELL} is lower than the safe voltage V_{SAFE} , irrespective of the resistance level of the addressed cells **13**.

The dummy resistor **32** is sized to balance the decoding voltage V_{DEC} on the column decoder **15** and may be formed by as many series connected dummy transistors (not shown) as these may be in the decoding levels of the column decoder **15**.

The reference select device **35** may be a bipolar PNP transistor identical to cell select devices **13b** of the cells **13**. Base and collector terminals of the reference selector **35** are connected to the ground line **24** and the emitter terminal is connected to the reference resistor **33**, so that the reference select device **35** and the cell select devices **13b** of the selected cells **13** are in the same configuration (in practice, they are diode-connected).

Thus, when the safe current I_{SAFE} flows through the voltage control circuit **28**, the bias voltage V_{GC} on the gate terminals of the bias transistor **31** and of the cascode transistor **27** is:

$$V_{GC} = V_{RSEL} + V_{SAFE} + V_{DEC} + V_{TN} + V_{OV} \quad (1)$$

where V_{RSEL} is the voltage on the reference select device **31**, V_{TN} is a threshold voltage of the bias transistor **31** and V_{OV} is an overdrive voltage of the bias transistor **31**. The overdrive voltage V_{OV} of the bias transistor **31** is normally negligible and will no longer be considered hereinafter, for this reason.

The bias transistor **31** and the cascode transistor **27** may have the same threshold voltage V_{TN} , since they match, and the decoding voltage V_{DEC} on the column decoder **15** is balanced by equal voltage drop on the dummy resistor **32** of the reading column bias circuits **25**. Thus, a bitline voltage V_{BL} on the selected bitline **22** is:

$$V_{BL} = V_{GC} - V_{DEC} - V_{TN} = V_{RSEL} + V_{SAFE} \quad (2)$$

In equation 2, an overdrive voltage of the cascode transistor **27** has been neglected, since it is substantially the same as the overdrive voltage V_{OV} of the bias transistor **31**.

Accordingly, the bitline voltage V_{BL} is fixed and is not subject to variations. The bitline voltage V_{BL} is also given by:

$$V_{BL} = V_{CSEL} + V_{CELL} \quad (3)$$

where V_{CSEL} is a cell select device voltage on the cell select device **13b** of the selected cell **13**. When the cell current I_{CELL} flowing through the selected cell **13** equals the safe current I_{SAFE} , the cell select device voltage V_{CSEL} is equal to the reference select device voltage V_{RSEL} . In other words, the reference select device voltage V_{RSEL} is equal to the cell select device voltage V_{CSEL} corresponding to the safe current I_{SAFE} .

So, in case a cell voltage V_{CELL} greater than the safe voltage V_{SAFE} is dropped across the phase change memory element **13a** (e.g. on account of noise or wear of components), the cell select device voltage V_{CSEL} is lower than the reference select device voltage V_{RSEL} . Accordingly, only a cell current I_{CELL} lower than the safe current I_{SAFE} is allowed by the cell select device **13b**.

If, on the contrary, the cell current I_{CELL} exceeds the safe current I_{SAFE} , the cell selector voltage V_{CSEL} is greater than the reference selector voltage V_{RSEL} . Since the bitline voltage V_{BL} is fixed, in this case the cell voltage V_{CELL} falls below the safe voltage V_{SAFE} .

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In either condition, at least one of the cell voltage V_{CELL} and the cell current I_{CELL} is lower than the respective safety parameter (i.e. the safe voltage V_{SAFE} and the safe current I_{SAFE}). This assures that the outcome of reading operation is correct and is not affected by noise or other disturbs that may intervene.

A second embodiment is illustrated in FIG. 4, where parts already shown are indicated by the same reference numbers. In this case, a phase change memory device **100** comprises the array **12** of PCM cells **13**, the column decoder **15**, the row decoder **16**, the sense stage **18** and a reading column bias stage **120**.

The reading column bias stage **120** includes a plurality of reading column bias circuits **125**, coupled to a respective sense amplifiers **21**. Each reading column bias circuit **125**, one of which is illustrated in detail in FIG. 4, comprise a cascode transistor **127** and a voltage control circuit **128**, for providing a controlled bias voltage V_{GC} on a gate terminal of the cascode transistor **127**. In the embodiment herein described, the cascode transistor **127** is a NMOS transistor and has its drain terminal connected to a respective sense amplifier **21** and source terminal connected to the column decoder **15** for coupling with an addressed bitline **22**.

The voltage control circuit **128** comprises a first current source **129**, a second current source **130**, a diode-connected bias transistor **131**, a dummy resistor **132**, a reference resistor **133** and a reference selector **135**.

The first current source **129** is connected to the voltage supply line **36** and is configured to supply a predetermined safe current I_{SAFE} to an emitter terminal of the reference selector **135**, that is connected to a reference node **137**. Base and collector terminals of the reference selector **135** are connected to the ground line **24**. The safe current I_{SAFE} is selected so that if a read cell current I_{CELL} , that flows through an addressed cells **13** during reading operation, is lower than the safe current I_{SAFE} , reading is not affected by disturbs, whatever the read cell voltage V_{CELL} dropping on the phase change memory element **13a** of the addressed cells **13**. In particular, phase transition of the phase change memory element **13a** is prevented in any bias condition such that the read cell current I_{CELL} is lower than the safe current I_{SAFE} , irrespective of the resistance level of the addressed cells **13**.

The bias transistor **131**, the dummy resistor **132** and the reference resistor **133** are connected in series between a supply terminal **130a** of the second source **130** and the reference node **137**. The second current source **130** provides a reference current I_0 at the supply terminal **130a** and draws the same reference current I_0 from the reference node **137**. In nominal temperature conditions, the reference current I_0 equals the safety current I_{SAFE} .

The bias transistor **131** may be an NMOS transistor designed to match the cascode transistor **127**. The gate terminal of the bias transistor **131** provides the bias voltage V_{GC} and is directly connected to the gate terminal of the cascode transistor **127**.

A first resistance value R_1 of the reference resistor **133** is such that a predetermined safe voltage V_{SAFE} dropped across it when the second current source **130** supplies the reference current I_0 , independently of temperature variations. The safe voltage V_{SAFE} is in turn selected so that if the read cell voltage V_{CELL} that drops on the phase change memory element **13a** of an addressed cells **13** during reading operation, is lower than the safe voltage V_{SAFE} , reading is not affected by disturbs, whatever the read cell current I_{CELL} flowing through the addressed cells **13**. In particular, phase transition of the phase change memory element **13a** is prevented in any bias condi-

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tion such that the read cell voltage V_{CELL} is lower than the safety voltage V_{SAFE} , irrespective of the resistance level of the addressed cells **13**.

The dummy resistor **132** is sized to balance the decoding voltage V_{DEC} on the column decoder **15** and may be formed by as many series connected dummy transistors (not shown) as the decoding levels of the column decoder **15**.

The second current source **130** comprises a band-gap voltage generator **140**, a bias fixing resistor **141**, a multiple-output PMOS current mirror **142** and a NMOS current mirror **143**.

The band-gap voltage generator **140** supplies a band-gap voltage V_{BG} , that is constant and independent of temperature variations and is applied to a bias fixing node **145** by means of a buffer **147**.

The bias fixing resistor **141** has a second resistance value R_2 and is connected between the bias fixing node **145** and the ground line **24**.

The PMOS current mirror **142** comprises a PMOS sense transistor **148**, a first PMOS mirror transistor **149** and a second PMOS mirror transistor **150**, all having common gate terminals and source terminals connected to the voltage supply line **36**. The drain terminal of the PMOS sense transistor **148** is connected to the bias fixing node **145**, for sensing the current flowing through the bias fixing resistor **141**. The drain terminal of the first PMOS mirror transistor **149** is coupled to the NMOS current mirror **143**, whereas the drain terminal of the second PMOS mirror transistor **150** forms the supply terminal **130a** of the second source **130**.

The NMOS current mirror **142** comprises a NMOS sense transistor **152** and a NMOS mirror transistor **153**, which have common gate terminals and source terminals connected to the ground line **24**. The drain terminals of the NMOS sense transistor **152** and of the NMOS mirror transistor **153** are connected to the drain terminal of the first PMOS transistor **149** and to the reference node **137**, respectively. The reading column bias circuit **125** operates as follows. The first current source **129** and the reference selector **135** set the reference node **137** at a reference selector voltage V_{RSEL} . The reference selector voltage V_{RSEL} is equal to a cell selector voltage V_{CSEL} on the cell selector **13b** of the selected memory cell when a cell current I_{CELL} flowing therethrough is equal to the safe current I_{SAFE} . The safe current I_{SAFE} flowing through the reference selector **135** is not affected by the connection of its emitter terminal to the reference node **137**, because the same reference current I_0 is simultaneously injected into and drawn from the reference node **137** by the second current source **130**.

The reference current I_0 supplied by the second current source **130** depends on temperature in such a way to compensate temperature dependence of the reference resistor **133** and to make the safe voltage V_{SAFE} on the reference resistor **133** immune from temperature variations.

The reference current I_0 is in fact obtained by multiple mirroring of a bias fixing current I_F flowing through the bias fixing resistor **141** on account of the band-gap voltage V_{BG} applied to the bias fixing node **145**.

Therefore, the bias fixing current I_F is

$$I_{BF} = V_{BG}/R_2 \quad (4)$$

and depends on temperature because it is determined by the second resistance value R_2 of the bias fixing resistor **141**.

The bias fixing current I_{BF} is sensed by the PMOS sense transistor **148** and mirrored by the first PMOS transistor **149** and by the second PMOS transistor **150**, that respectively provide an intermediate bias fixing current I_{IBF} and the refer-

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ence current I_0 (both equal to the bias fixing current I_{BF}). The intermediate bias fixing current I_{IBF} is in turn mirrored by the NMOS current mirror **143**, that draws the reference current I_0 from the reference node **137**.

Accordingly, the reference current I_0 and the safety voltage V_{SAFE} on the reference resistor **133** is:

$$I_0 = I_{IBF} = I_{BF} = V_{BG}/R_2 \quad (5b)$$

$$V_{SAFE} = R_1 I_0 = V_{BG} R_1 / R_2 \quad (5b)$$

Thus, temperature variations of the first resistance value R_1 are cancelled by temperature variations of the second resistance value R_2 .

Therefore, appropriate bias conditions, with at least one of the cell voltage V_{CELL} and the cell current I_{CELL} lower than the respective parameter V_{SAFE} , I_{SAFE} , are met irrespective of temperature variations.

According to equation (2), that is in fact still valid, the bitline voltage V_{BL} on the selected bitline **22** is determined by the safe voltage V_{SAFE} and by the reference selector voltage V_{RSEL} only. As explained above, the safe voltage V_{SAFE} is not affected by temperature. In addition, the first current source **129** is temperature independent and therefore the safe current I_{SAFE} is stable. Thus, although the reference selector voltage V_{RSEL} may be affected in itself by temperature drift (as well as the cell selector voltage V_{CSEL}), at any time the reference selector **135** provides a correct reference to compensate cell currents I_{CELL} exceeding the safe current I_{SAFE} .

According to a third embodiment that is illustrated in FIG. **5**, a phase change memory device **200** comprises the array **12** of cells **13**, the column decoder **15**, the row decoder **16**, the sense stage **18** and a reading column bias circuit **225**. The reading column bias circuit **225** comprises a voltage control circuit **228** and a plurality of cascode transistors **227**, coupled to respective sense amplifiers **21**.

The voltage control circuit **228** has the same structure as the voltage control circuit **28** of FIG. **2** and comprises a voltage source **229**, a bias transistor **231**, a dummy resistor **232**, a reference resistor **233** and a reference selector **235**. Hence, a bias voltage V_{GC} according to equation (1) is provided on a gate terminal of the bias transistor **231**.

In one embodiment not shown, the voltage control circuit **228** has the same structure as the voltage control circuit **128** of FIG. **4**.

The N-type cascode transistors **227** have drain terminals connected to respective sense amplifiers **21** and source terminals connected to the column decoder **15**, for coupling with addressed bitlines **22** during read operations. Gate terminals of the cascode transistors **227** are all connected to the gate terminal of the bias transistor **231**, for receiving the bias voltage V_{GC} . A reduction of circuit dimension may be achieved in some embodiments.

In one embodiment (FIG. **6**), a reading column bias circuit **325** comprises a voltage control circuit **328** and at least one cascode transistor **327** coupled thereto. An array of N parallel-connected reference resistors **333** is used in the voltage control circuit **328** in place of a single reference resistor and is connected to a voltage source **329**, that provides the safe current I_{SAFE} , a bias transistor **331**, a dummy resistor **332** and to a reference selector **335**. An overall resistance value of the array of reference resistors **333** is such that the safe voltage V_{SAFE} drops on it when the safe current I_{SAFE} is provided by the bias transistor **331**. Sensitivity to process spread may be reduced in some embodiments.

In another embodiment (FIG. **7**), a reading column bias circuit **425** comprises a voltage control circuit **428** and at least one cascode transistor **427** coupled thereto. The voltage con-

troil circuit **428** in turn comprises a voltage source **429**, a bias transistor **431**, a dummy resistor **432**, a reference resistor **433** and an array of N parallel-connected reference selectors **435**, each of which is configured to draw the safe current I_{SAFE} . In this case, an overall current equal to NI_{SAFE} is provided by the current source **429** and flows through the reference resistor **433**, that is designed to cause a voltage drop equal to V_{SAFE} . In other words, a resistance value of the reference resistor **433** is $R = V_{SAFE} / NI_{SAFE}$.

In FIG. **8**, a portion of a system **500** in accordance with an embodiment of the present invention is illustrated. System **500** may be used in devices such as, for example, a personal digital assistant (PDA), a laptop or portable computer, possibly with wireless capability, a cellphone, a messaging device, a digital music player, a digital camera, or other devices that may be adapted to process, store, transmit or receive information and require permanent storage capability.

System **500** may include a controller **510**, an input/output (I/O) device **520** (e.g. a keyboard, display), the phase change memory device **10**, a wireless interface **540**, and a RAM memory **560**, coupled to each other via a bus **550**. A battery **580** may be used to supply power to the system **500** in one embodiment. It should be noted that the scope of the present invention is not limited to embodiments having necessarily any or all of above listed components.

Controller **510** may comprise, for example, one or more microprocessors, digital signal processors, micro-controllers, or the like.

The I/O device **520** may be used to generate a message. The system **500** may use the wireless interface **540** to transmit and receive messages to and from a wireless communication network with a radio frequency (RF) signal. Examples of the wireless interface **540** may include an antenna, or a wireless transceiver, such as a dipole antenna, although the scope of the present invention is not limited in this respect. Also, the I/O device **520** may deliver a voltage reflecting what is stored as either a digital output (if digital information was stored), or as analog information (if analog information was stored).

References throughout this specification to "one embodiment" or "an embodiment" mean that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one implementation encompassed within the present invention. Thus, appearances of the phrase "one embodiment" or "in an embodiment" are not necessarily referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be instituted in other suitable forms other than the particular embodiment illustrated and all such forms may be encompassed within the claims of the present application.

While the present invention has been described with respect to a limited number of embodiments, those skilled in the art will appreciate numerous modifications and variations therefrom. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of this present invention.

What is claimed is:

1. A phase change memory device comprising:
 - a cell including a phase change memory element and a select device; and
 - a reading bias circuit to supply a cell voltage equal to a voltage on the select device when a cell current is equal to a safe current and wherein a safe voltage and the safe current are such that phase transition of the phase change memory element is prevented in any bias condition.
2. The device of claim **1** wherein the reading column bias circuit comprises a reference resistor, a reference select device, matching the cell select devices and a current genera-

tor circuit to supply current to the reference resistor and the reference select device such that the safe voltage drops across the reference resistor and the safe current flows through the reference select device.

3. The device of claim **2** wherein the reading column bias circuit further comprises a cascode transistor and a bias transistor having control terminals connected together and wherein the cascode transistor has a conduction terminal coupled to the addressed bitline and the bias transistor has a conduction terminal coupled to the reference resistor.

4. The device of claim **3** including an addressing circuit, wherein the reading column bias circuit further comprises a dummy resistive element to compensate a decoding voltage drop across the addressing circuit.

5. The device of claim **3** wherein the bias transistor, the reference resistor, and the reference select devices are series-connected.

6. The device of claim **5** wherein the current generator circuit comprises a current source to supply the safe current to the bias transistor, the reference resistor, and the reference select device.

7. The device of claim **3** wherein the bias transistor and the reference resistor are series-connected and the reference select device has a conduction terminal connected to the reference resistor.

8. The device of claim **7** wherein the current generator circuit comprises a first current source to supply the safe current to the reference select device, and a second current source to supply a temperature-compensated reference current to the reference resistor to compensate temperature dependence of the reference resistor.

9. The device of claim **8** wherein the second current source comprises:

- a bias fixing resistor;
- a temperature-independent voltage source to provide a temperature-independent voltage across the bias fixing resistor; and
- current mirror circuits to mirror a current flowing through the bias fixing resistor and supply the reference current to the reference resistor.

10. The device of claim **9** wherein the current mirror circuits comprise a first current mirror to inject the reference current into the reference resistor and a second current mirror to draw the reference current from the reference resistor.

11. A system comprising:

- a processor; and
- a phase change memory device coupled to said processor, said device comprising a cell including a phase change memory element and a select device, and a cell voltage equal to a voltage on the select device when a cell current is equal to a safe current and wherein a safe voltage and the safe current are such that phase transition of the phase change memory element is prevented in any bias condition.

12. The system of claim **11** wherein the reading bias circuit comprises a reference resistor, a reference select device, matching the select device and a current generator circuit to supply current to the reference resistor and the reference select devices such that the safe voltage drops across the reference resistor and the safe current flows through the reference select device.

13. The system of claim **12** wherein the reading column bias circuit further comprises a cascode transistor and a bias transistor having control terminals connected together and wherein the cascode transistor has a conduction terminal coupled to the addressed bitline and the bias transistor has a conduction terminal coupled to the reference resistor.

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- 14.** A method comprising:
 biasing a phase change memory cell including a select
 device and memory element with a cell voltage equal to
 a voltage on the select device when a cell current is equal
 to a safe current and wherein a safe voltage and the safe
 current are such that phase transition of the phase change
 memory element is prevented in any bias condition. 5
- 15.** The method of claim **14** wherein biasing comprises:
 providing a reference resistor and a reference select device,
 matching the select device; and
 supplying current to the reference resistor and the refer-
 ence select device such that the safe voltage drops across
 the reference resistor and the safe current flows through
 the reference select device. 10
- 16.** The method of claim **15** including connecting the ref-
 erence resistor and the reference select device in series,
 wherein biasing includes supplying the safe current to the
 reference resistor and the reference select device. 15

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- 17.** The method of claim **15** wherein biasing comprises:
 supplying the safe current to the reference select device;
 and
 supplying a temperature-compensated reference current to
 the reference resistor to compensate temperature depen-
 dence of the reference resistor.
- 18.** The method of claim **17** wherein supplying the safe
 current comprises:
 applying a temperature-independent voltage across a bias
 fixing resistor; and
 mirroring a current flowing through the bias fixing resistor
 to supply the reference current to the reference resistor.
- 19.** The method of claim **18** wherein supplying the safe
 current comprises injecting the reference current into the
 reference resistor and drawing the reference current from the
 reference resistor.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 7,848,138 B2
APPLICATION NO. : 11/809702
DATED : December 7, 2010
INVENTOR(S) : Ferdinando Bedeschi et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 7:

Line 65, "the reading column bias" should be --the reading bias--;

Line 67, "matching the cell select" should be --matching the select--;

Column 8:

Line 5, "the reading column bias" should be --the reading bias--;

Column 9:

Line 6, "arc" should be --are--.

Signed and Sealed this
Fourteenth Day of June, 2011

A handwritten signature in black ink that reads "David J. Kappos". The signature is written in a cursive, slightly slanted style.

David J. Kappos
Director of the United States Patent and Trademark Office